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ABSTRACT

Employers and school admissions officials must consider several factors when making choices among applicants, particularly when faced with a need to increase selection of minority group members. Should different standards be applied to different groups? Will acceptance of less qualified applicants from one group affect the overall quality of the work force or the student body? How much does the particular situation affect the degree of change in overall quality? How much of a drop in quality is acceptable? How does that drop in quality balance with the benefits to be obtained from increasing the employment or admission of minority group members? Such questions can be addressed by making a numerical estimate of the tradeoffs involved. The mathematical process for making such estimates can be used to test different policies for selecting employees or admitting students. The most beneficial policy can then be determined. This document describes the mathematical process and its application, and provides an example of the process in use. (PGD)

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SETTING CUT SCORES IN SELECTION: A MATHEMATICAL STRUCTURE FOR EXAMINING POLICIES

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Setting cut scores in selection: A mathematical structure for evaluating policies

The fairness of procedures used to choose applicants should be examined closely, for legal and practical reasons. Fairness, however, is open to many interpretations (Flaugher, 1978). Professional norms and legal standards are being worked out by a slow process of argumentation (Darlington, 1971; Symposium, 1976; Novick and Ellis, 1977; Lerner, 1978). Resolution will be difficult at best, because the questions are political as well as intellectual.

Though political discussions increasingly focus on the costs and benefits of regulations, the tradeoffs between "equal opportunity" and "business necessity" have rarely been analyzed. To assist in examining guidelines and selection procedures, this paper formalizes concepts for describing consequences of selection. The argument is mathematical, but we simplify where possible and provide a nontechnical summary. Although the formulation should be suggestive for policy, its primary function is to lay the ground for more comprehensive studies of selection in both hypothetical and actual instances.

Information that predicts success is used to choose applicants. (Hereafter we speak of "hires". Readers concerned with educational selection should think of "hires" as "admits".) Predictor information may come from tests, personal history, interviews, and other sources. For purposes of formal argument we speak as if persons below a certain score on a single summary measure X are rejected, though information is ordinarily used more flexibly.

Traditional selection is "group blind"; a single cut score is applied to all applicants without regard to group membership. In principle,

group-specific cut scores could be set; such schemes have been advocated and occasionally used. The question addressed here is: How do shifts in the group-specific cut scores alter indices of fairness and the quality of those selected? We propose a way to examine this question and present an illustrative case.

Assumptions and Symbols

Many terms and symbols are needed; Table 1 and Figure 1 summarize notations that will enter the discussion gradually.

Utility Rule

This paper grows out of a tradition of examing personnel decisions in terms of "utility" (J. Campbell, 1976; Novick and Peterson, 1976). It is common to make utility a linear function of the measure of job performance Y (e.g., Hunter, Schmidt, and Rauschenberger, 1977), but to simplify the presentation we adopt a "threshold utility" scheme. This all-or-none model has a long history (Taylor and Russell, 1939). Our indices can be applied even where threshold utilities are inappropriate.

The threshold rule classes workers as satisfactory if their criterion performance is at or above a certain level Y^*, and as unsatisfactory otherwise. Utility is assumed to be uniform at an arbitrary value of one for all satisfactory workers, and zero for all unsatisfactory workers. Threshold utilities are realistic, if approximate, where

differences in productivity among adequate workers are small because of constraints such as the pace of an assembly line. Lerner argues that, above the level where students complete legal training, differences in law-school grade averages indicate little about the social contribution the graduates will make. This line of thought suggests that threshold utilities suitably represent the grade criterion.

Variables, distributions, and cut scores.

Two applicant groups, A and B, are considered. The argument and computational procedures extend to multiple groups. The pool of applicants for a particular job in one firm is labeled population G (for "grand"). G is the union of subpopulations A and B ; these are distinguished by ethnic, sex, or other characteristics. In our illustrative case, B is the smaller group and has a lower average criterion score. In another case the minority might have the higher scores. Our model is symmetric; analysis can focus on either group. Symbols in Table 1, and Figure 1, refer to A ; counterparts could be prepared for Group B . Thus, the proportion π_A of G are members of A ; π_B ($= 1 - \pi_A$) are members of B . The subscript G is used where symbols are applied to both groups together.

The outcome measure Y is assumed to be relevant and unbiased. As in all theory of selection, we presume that the employer knows the joint distribution of X and Y in the applicant populations. This is unrealistic, because only the hires are observed on the job and they are

rarely representative of all applicants. Thorough understanding of hypothetical cases, however, provides a starting point for practical rules.

A cut score is set for the group, and members who score above that level are hired. The selection ratio ϕ_G is the number of vacancies divided by the size of the entire applicant pool; it is fixed in any one selection situation. Other things being equal, raising the cut score X_A^* reduces the percentage of A's selected; to fill the vacancies, X_B^* is shifted downward. ϕ_A is the proportion of Group A reaching the cutting score X_A^*. The selection ratio ϕ_G equals $\pi_A\phi_A + \pi_B\phi_B$. We use the percentage of minority hires (MH), which equals $100\ \pi_B\phi_B/\phi_G$, as a summary index. We assume that within each group the expected quality of work increases as X increases (unless $\rho_{XY} = 0$).

Quality of Applicants and Hires

The appropriate index of the quality of a group is the average utility measure. With threshold utilities, the average is the fraction of the group for whom $Y > Y^*$. The proportion of A applicants who would be satisfactory if hired, θ_A, describes the quality of A applicants. θ_G describes the quality of the total pool.

In Figure 1, the upper right quadrant of the distribution contains persons who are hired and satisfactory. Each has a postulated utility of 1. These persons in Group A, plus the counterpart members

of Group B , constitute the fraction α_G of G . We let $\gamma_G = \alpha_G/\phi_G$; this average utility measure will be referred to as QH , for Quality of Hires.

QH can be adequately interpreted only in light of its possible range. With chance selection, QH equals θ_G . With perfectly valid prediction ($\rho_{XY} = 1$) , QH can reach 1.00 or θ_G/ϕ_G , whichever is smaller. For example, if $\theta_G = 0.30$ and 50% of all applicants must be hired, then not more than 60% of hires will be satisfactory.

Even though QH is derived from a utility scale, it is a means only of ordering alternative selection rules. The value implied by QH has to be judged by the circumstances. A level of QH adequate in one trade may be seriously low in another. Some firms would go bankrupt or lose their licenses if fewer than 90% of the employees were satisfactory. In another trade it may be usual for 25% of the employees to fall below the level called satisfactory.

Indices of Bias

Three concepts of bias in selection are prominent in the literature: adverse impact, adverse impact on satisfactory applicants, and unequal treatment of equally promising applicants. We define three corresponding indices. As with QH , the indices are to be interpreted in the light of the range of values the situation allows, and they serve only to order alternative decision rules. A situation-specific judgment is required to evaluate the seriousness of a particular increase in one of the indices. In maximally discriminatory selection the employer gives

preference to members of one group, hiring from the second group only if vacancies remain after the first group is exhausted. Thus, when ϕ_A is at its minimum, the indices of discrimination against A's reach their maxima. When ϕ_G is fixed, π_A determines the largest and smallest allowable ϕ_A and ϕ_B.

Bias can run in either direction. Each index of bias is zero when there is no bias of the kind the index represents; positive numbers indicate bias against a specified group. Thus, for adverse impact, we speak of AI_A (adverse impact against A's) and AI_B.

Adverse impact (AI). A selection procedure is said to have "adverse impact" on Group A when applicants from Group A are less likely to be hired than others. Under the Uniform Federal Guidelines* (Federal Register, August 25, 1978), a selection procedure with little or no adverse impact is accepted prima facie as not in violation of the Civil Rights Act. If the procedure has appreciable adverse impact, the employer must defend against the charge that the procedure discriminates by showing that selection standards are related to requirements of the job.

We adopt $\phi_G - \phi_A$ as a simple indicator of adverse impact against A's. This differs from the "four-fifths rule" embodied in the Guidelines, but it is consistent with the intent. The four-fifths rule takes adverse impact to be serious when (in our notation) ϕ_A/ϕ_B or ϕ_B/ϕ_A is less than .80. This index is sensitive only to disparities in rates of hiring; our index is sensitive also to disparities in rejections. The ratio of ϕ's can have anomalous properties when the applicant groups differ in size. If 90% of the applicants must be hired to fill the vacancies, and only 30% of all applicants are

B's, an employer seeking to discriminate against A's will hire 30 out of 30 B's and 60 out of 70 A's. Then $\phi_A = .86$ and $\phi_B = 1.00$; the disparity does not trigger the four-fifths rule. The proportions rejected, however, are conspicuously different: 14 per cent versus zero. The "Questions and Answers" document issued to clarify the Guidelines (Federal Register, March 2, 1979) indicates that such a disparity in rejections, if found in a large sample, would be regarded as serious.

In the legal determination of adverse impact, calculations are to be based on the number of "available" workers from Group A and Group B. We have based our index on the number of applicants, but othe. interpretations may enter a legal controversy. Members of the community who do not apply for a particular job may be counted, if it is contended that a firm has not encouraged minority applications. On the other side, the employer may argue for counting only qualified persons rather than all persons seeking work.

Adverse impact on satisfactory applicants (AIS). Some would say that selection is fair if A's and B's who would be satisfactory on the job are equally likely to be hired. We speak of this concept as AIS: adverse impact on satisfactory applicants. AIS embodies the "group parity" concept of Cole (1973) and Sawyer, Cole, and Cole (1976). Attention focuses on λ_A (= α_A/θ_A) and λ_B . With no AIS, $\lambda_G = \lambda_A = \lambda_B$. The index AIS_A is defined as $\lambda_G - \lambda_A$.

Difference in quality at the margin (DQM). It is hard to defend X as an indicator of merit unless A's and B's with the same X score

have the same expected utility (Ash, 1966; Cleary, 1968). Merit hiring seems to embody the idea that A's at the cut score X_A^* should have the same expected utility as the B's at X_B^*. With threshold utilities, expected utility is equivalent to success rate. The success rate of A's at the cutting score is denoted by ψ. The difference in quality at the margin DQM_A equals $\psi_A - \psi_B$; a positive value implies discrimination against A's. DQM_B equals $\psi_B - \psi_A$.

Comment. The three indicators of discrimination or bias evaluate selection rules in the same way only in special cases (in particular, when $\rho_{XY} = 1$ in population G). A procedure judged nondiscriminatory by one index will generally show some discrimination according to the other indices.

Our indices do not represent all concepts of bias. We ignore the concept of "equal risk" (Einhorn and Bass, 1971), and Thorndike's (1971) proposal to compare ϕ_A/θ_A with ϕ_B/θ_B. Unlike AI, AIS, and DQM, these two concepts do not appear to express utilities of employers or applicants (Cronbach, 1976). Novick and Peterson object to the AIS concept because it ignores the outcome for workers who would be unsatisfactory if hired; but policy-makers and the courts do not see this as an important aspect of fairness.

Selection Strategies

A selection strategy is a policy for setting cut scores. Writers discussing certain strategies speak of them as alternative "models" of fairness, but this is inappropriate. The single "model" -- i.e., mathematical representation -- of the present paper embraces a great number of strategies.

Cut scores are continuously adjustable, and cutoffs that express particular strategies can be located.

Group-blind hiring. Conventional hiring with a single-cutting score ignores group membership. Then $X_A^* = X_B^*$: the common cut score may be referred to as X^*.

Quota. Quotas can be arbitrary, but quotas proportional to π_A and π_B are of particular interest. Then $\phi_A = \phi_B = \phi_G$ and $AI = 0$.

Adjusted quota. The quota can be made proportional to α_A/θ_A. Then $\lambda_A = \lambda_B = \lambda_G$ and $AIS = 0$.

Equal marginal risk. If merit is identified with expected utility, cut scores are set so that $\psi_A = \psi_B$ and $DQM = 0$. This rule maximizes QH.

Procedures and Results

Specification and Calculation

The numerical values of the indices depend on the selection situation and the cut scores. The situation is defined by the selection ratio, the conversion of Y to a utility scale (which we do by setting Y*), the joint X, Y distribution within each group, and π_A. This analysis can be made for joint distributions of any form. The calculations are simple if the distributions are bivariate normal.

The calculations proceed as follows with threshold utilities:

1. θ_B, θ_B, and θ_G are determined, using Y* and the group means and variances on Y.
2. π_A and ϕ_G determine maximum and minimum admissible values of ϕ_A. Each ϕ_A within this range can be paired

with just one ϕ_B, under the constraint set by ϕ_G. Successive values for ϕ_A are set, spaced over the range of admissible values. For each of these, we calculate α_A, ψ_A, and X^*_A (as a standard score), and the corresponding ϕ_3, α_B, ψ_B, and X^*_B.

3. For each ϕ_A, ϕ_B pair the corresponding MH is calculated.
4. Values of α_G are obtained as weighted sums of the paired α_A, α_B.
5. QH, AI, AIS, and DQM are calculated and examined as a function of MH.

In group-blind hiring, just one common cut score X* fills the specified number of places. The value of X* depends on the parameters considered earlier and also on the overlap of groups on X. Assuming X to be normally distributed, the mean and standard deviation of X in each group as additional parameters. The X* corresponding to ϕ_G is found by trial and error. Once X* is located, the corresponding ϕ_A and ϕ_B imply values of MH, QH, DQM, AI, and AIS. More direct procedures are available for special cases such as the one below which the Y-on-X regressions are parallel and the within-group s.d.'s equal.

An illustrative case

Results for one case appear in Figure 2. The following values are assumed:

$\sigma_X = \sigma_Y = 1$ within each group; $\rho_{XY} = .40$ within each group;

$\pi_A = .80$; $\phi_G = .50$.

$\mu_{Y(A)} - \mu_{Y(B)}$ is set at 0.5 σ_Y, and Y* is set at one-half s.d. above the grand mean.

As a consequence $\theta_G = .3125$, $\theta_A = .34$, and $\theta_B = .18$. Since $\pi_B/\phi_G = .40$, MH can range from 0% to 40%. It is found that AI, AIS, and DOM, respectively, have zero values with MH at 20%, 18%, and 6%. The group-blind strategy produces zero DQM if and only if the Y - on - X regressions coincide. In the present case the regressions coincide when the group means are separated by $1.25\ s_X$, if s_X is the same in both groups.

The chance baseline for QH is .3125. QH reaches its maximum of .439 when MH is 6% (where DQM = 0). At the extremes of MH (0% and 40%), the respective values of QH are .433 and .374.

Hunter, Schmidt, and Rauschenberger reached essentially the same results for this illustrative case, using a linear utility function and confining attention to a few cut scores. Their paper also reports calculations for numerous additional values of π_A, ϕ_G, and ρ_{XY}.

The flatness of the QH curve in Figure 2 is striking. The values of QH - θ_G is within 10% of its optimum over the range of MH from 0% to 20%. Thus the adjusted-quota strategy which would give 18% of the places to B's brings QH - θ_G to .116, compared to .126 for the equal marginal-risk strategy where B's get only 6% of the places.

Shallow QH curves will be found over a wide range of realistic parameters. This is evident from logical considerations, from limited analyses we have made of other cases, and from the results of Jones (Note 1), Cole and Hunger et al. With some parameters the drop-off in QH is great between the point where DQM is zero and the point where AI is zero. Other things being equal, the drop-off increases as ρ_{XY} increases, or $\mu_{Y(A)} - \mu_{Y(B)}$ increases (from zero), or as

r_G decreases. To reach a more complete and generalized statement, computations for many combinations of the parameters will be needed. That work is in progress.

Within a single population and a normal distribution the increase in quality of hires with moderate values of ρ_{XY} and $1 - \phi$ is nearly linear with either linear or threshold utilities (Taylor and Russell; Brogden, 1946; Cronbach and Gleser, 1965). Further research may show additional disparities between the utility scales in the more complicated two-group case or for other distributions. Even so, the present finding that these utility scales yield the same trend for a fairly typical parameter set has a broad implication. When the discontinuous zero-one function and the linear function generate similar results, results from an intermediate monotone increasing function (an ogive, for example) should be much the same. On the other hand, a utility function that increases rapidly in the upper part of the Y range is not intermediate to the functions studied so far; it may give a different result. We agree with Novick and Lindley (1978) that a wide range of functions should be examined before sweeping generalizations are made, but generalizing can begin before possibilities have been studied exhaustively.

Summary and Discussion

This paper offers a systematic conception of selection rules and policies. Employers, guideline writers, lawyers, and courts can use the concepts to pin down contradictions among definitions of fairness. There is a tradeoff between accepting more applicants from a low-scoring group and maximizing the quality of the work force or student body. An analysis like ours permits numerical estimates of the tradeoffs, which can be a basis for

recommendations about selection policies.

When there is a majority group A and a minority group B, the employer can alter the percentage of B's among those hired by applying a different cut score in each group. We represent the employers' interest by the index QH --essentially, average quality of those hired, defined on a carefully considered scale of job performance. Save in a few limiting cases, QH rises and then declines as this percentage is increased from its minimum. When B's tend to be less successful than A's, the curve relating QH to the rate of minority hiring suggests how much a particular increase in minority hiring costs the employer. In many selection situations, the curve is quite flat. Then a substantial increase in minority hiring decreases QH very little. In the case illustrated, doubling the proportion of minorities in the work force (from 6% to 12%) reduced QH by only 1%. The shape of the curve and the implications of greater minority hiring for the employer vary with the situation.

As Darlington, Hunter, et al., and other have pointed out, employers setting selection rules and those making "fair employment" policy weigh conflicting values. Ultimately policy must consider benefits to the public welfare, not merely benefit to the selecting institution. The distribution of talent among competing firms is important for the firms, but improving the staff of one firm at the expense of anoth does little for the economy. Aggregate utility will require new analytic approaches. This paper, however, is limited to the transaction of one firm with one pool of applicants. The benefit from improving QH is not limited to the employer's financial gain. Increasing

productivity and reducing accidents benefits the nation and the employee. Eliminating social disparities among demographic groups also benefits the nation, and intangible benefits, at least, accrue to the employer who is perceived as contributing to this cause. Both advancement on the basis of individual merit and giving special consideration to the less fortunate are acceptable principles of justice.

The values conflict. A rule that satisfies one of these values rarely satisfies other ideals of fairness. We have considered four hiring policies. One is "group blind" hiring, in which test scores are interpreted without regard to group membership; this avoids reverse discrimination, as the group that scores low on the test receives comparatively few places. The second is to hire on the basis of predicted job performance rather than test score; this procedure recognizes any differences among groups in the relation of performance to test score. This strategy maximizes the quality of the work force. Eliminating adverse impact entirely, i.e., quota hiring, has its advocates, and so does a plan that would adjust quotas according to the comparative quality of applicants from the two groups.

At present, neither the courts nor the community accept any one strategy as universally preferable and decision-makers seek a balance. Where the courts find it permissible to consider group membership in hiring, the question of balance takes a quantitative form. The law clearly authorizes employers to upgrade quality by selection; at what point does the increase in quality go beyond business necessity? At what point is an increase in minority hiring better justified than an increase in average employee quality?

The tradeoffs between QH and minority hiring have already been described for a range of important cases by Hunter, Schmidt, and Rauschenberger. Our more comprehensive scheme of analysis is consistent with theirs in all important respects. We plan to carry out computations for a wide range of hypothetical cases. This mapping, when complete, will indicate the circumstances under which additional minority hiring entails little loss in QH, and where it entails a great loss.

This paper does not advocate any one selection strategy. It accepts that some advocates will press for unalloyed "merit hiring", that some will press for "a representative work force", and that some others will favor intermediate policies. Our intention has been to provide a framework within which a pluralistic social system can critically examine selection schemes.

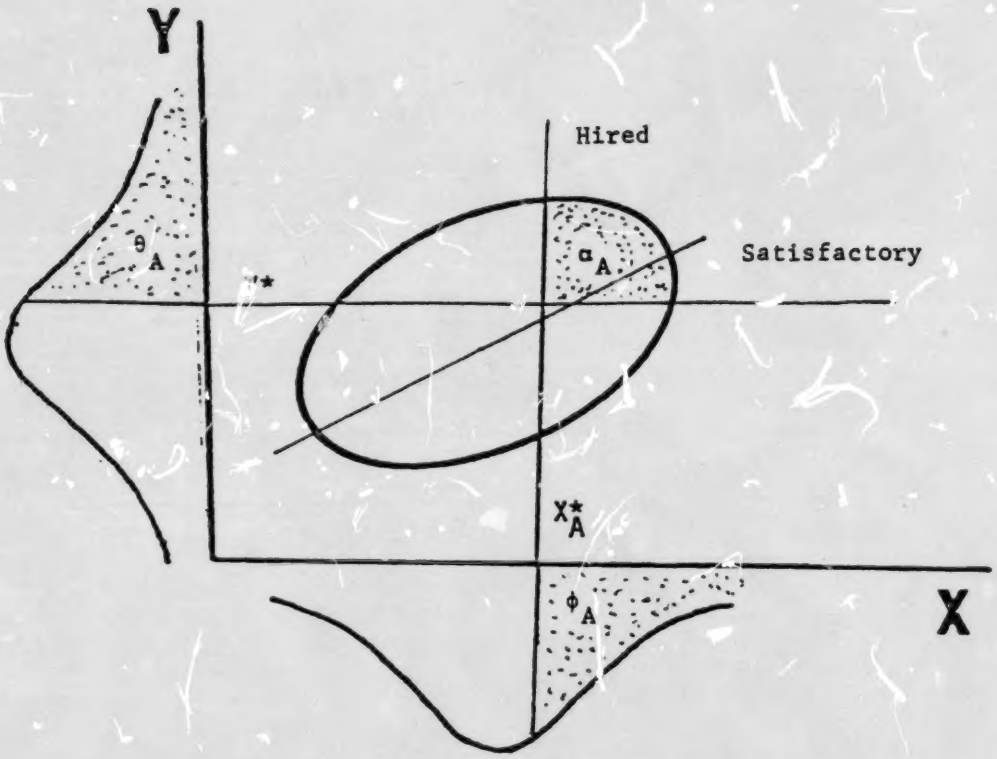

Figure 1. Schematic relation of predictor to outcome in Group A.

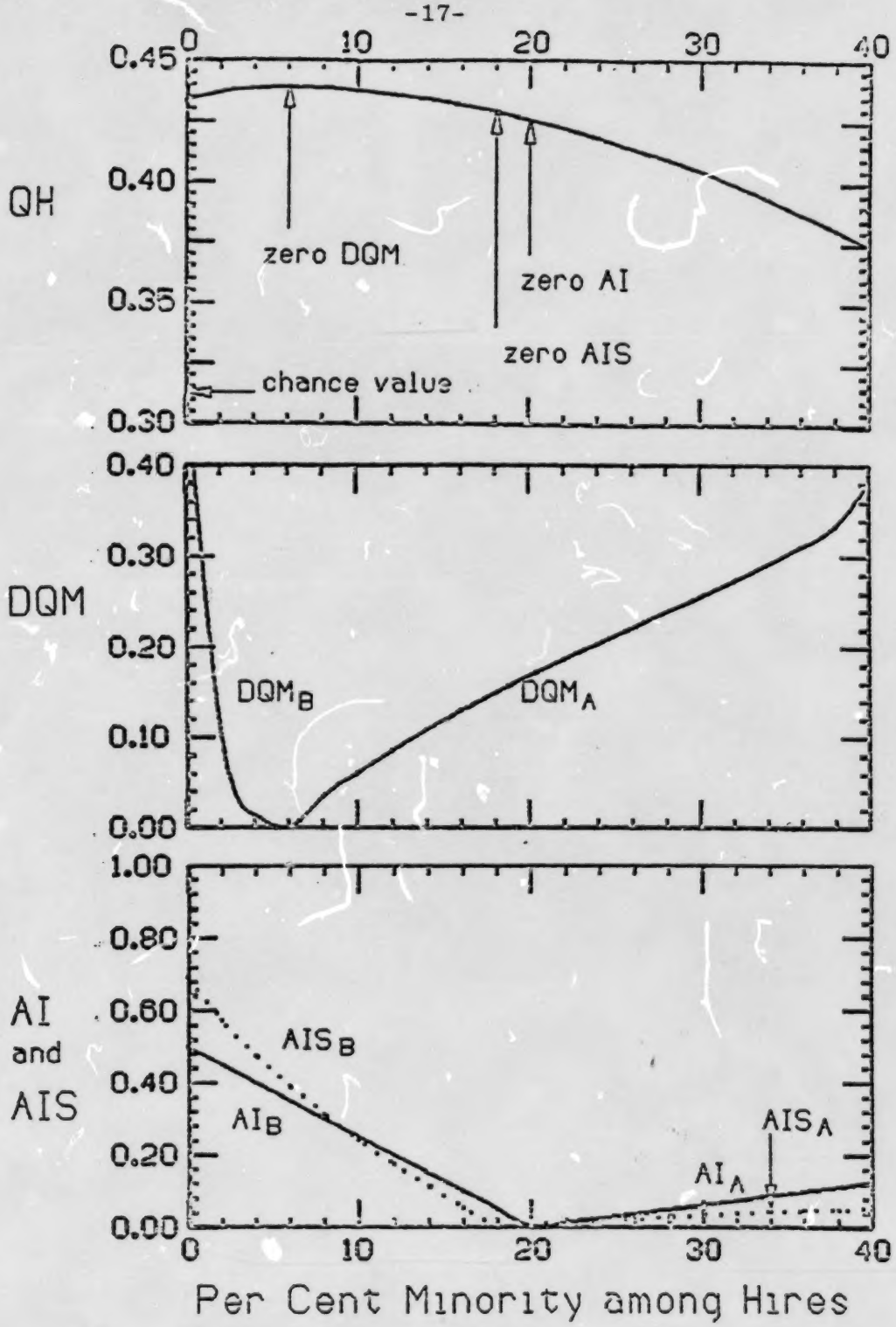

Figure 2. Results for one illustrative case.

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Table 1

Summary of notation

Y	Criterion measure of job performance
Y^*	Level above which employees are satisfactory
π_A	Among all applicants, the proportion belonging to Group A
θ_A	Proportion of A applicants who would be satisfactory if hired; i.e., for whom $Y \geq Y^*$
X	Test or other predictor score
X_A^*	Cut score for A applicants
X^*	Cut score if $X_A^* = X_B^*$
ϕ_A	Proportion of A applicants above X_A^*
α_A	Proportion of A applicants with $X \geq X_A^*$ and $Y \geq Y^*$
λ_A	α_A/θ_A ; proportion of satisfactory workers who have $X \geq X_A^*$
Ψ_A	Proportion of the A applicants at X_A^* (i.e., borderline hires) who are satisfactory
ϕ_G	Selection ratio; ratio of number of vacancies to the size of Population G
MH	Percentage of those hired who belong to Group B, equals $\pi_B \phi_B / \phi_G$
γ_G	α_G / ϕ_G ; proportion of satisfactory workers among those hired
AI_A	$\phi_G - \phi_A$
AIS_A	$\lambda_G - \lambda_A$
DQM_A	$\Psi_A - \Psi_B$